Temperature dependence of σ_{inv} in evaporation spectra

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The description of particle evaporation by a compound nucleus can be viewed as an entrance channel process of the time reversed reaction. However, two important points come out immediately. After evaporation from a moderately warm nucleus, the residual nucleus is still excited. Therefore the inverse process leads to a particle impinging on a *hot* nucleus. The second point is related to the shape polarization (or deformation) of the emitting nucleus which will tend to an elongated shape in the evaporation process and therefore modify the Coulomb interaction energy. Both of these effects are not accessible in elastic scattering experiments. Even more important, the extracted inverse cross-section used in most statistical models, is that for a *cold*, not *hot*, nucleus [1].

An expression for the evaporation spectra can be obtained from detailed balance:

$$\rho_a \Gamma_{a\to b} = \rho_b \Gamma_{b\to a}. \tag{1}$$

For particle emission, the right term can be expressed as a function of the inverse cross-section σ_{inv} and the residual nucleus level density ρ [1]:

$$P(E) \propto E\sigma_{inv}(E)\rho(E^* - B - E). \tag{2}$$

where $P(E)$ is the kinetic energy distribution, E^* is the total available energy, and B is its binding energy. Since we have a reasonable understanding of $\rho(E^* - B - E)$ [2], we can obtain experimentally the inverse cross-section by dividing out the phase space factor ρ from the evaporation spectra. Notice that σ_{inv} is not the inverse cross section for the particle incident on the *cold* residual nucleus. Rather, and importantly so, it is the cross section for a particle incident on the *hot* nucleus at its residual energy.

High statistics evaporation spectra were measured for the reaction ^{3}He+^{nat}Ag from 55 to 140 MeV. The experimental kinetic energy distributions were reproduced by using a formalism that takes into account the Coulomb barrier, the emission temperature and deformation of the nucleus along the particle emission axis [2]

$$P(\epsilon) \propto e^{-\epsilon/T}\mathrm{erfc}\left(\frac{\mathrm{p} - 2\epsilon}{2\sqrt{\mathrm{pT}}}\right) \tag{3}$$

where $\epsilon = E - B_c$ and p is the amplification parameter or "spring constant". Fits to the experimental data using Eq. (3) are of extremely high quality with residuals of the order of only 1% (cf. Fig. 3 of ref. [1]). In this description, emission below the barrier is possible due to a purely classical reason – because of deformation.

Inspection of Eqs. (2) and (3) reveals that once the background phase space is divided out, σ_{inv} is parameterized as the complementary error function. By taking the first derivative of σ_{inv}, it is possible to characterize the temperature dependence of σ_{inv} from the width of the resulting Gaussian distribution

$$\frac{d\sigma_{inv}}{d\epsilon} \propto \exp\left(-\frac{(\bar{\epsilon} - \epsilon)^2}{2\sigma^2}\right) \tag{4}$$

where $\bar{\epsilon} = p/2$ and $\sigma = \sqrt{pT/2}$. For ^{3}He+Ag reactions, p was found to be stable with a value of 1.72 MeV. A set of σ_{inv} and its first derivative for alpha evaporation from the composite system formed in the reaction ^{3}He+Ag is shown in Fig. 1. The change in width (σ) from 55 to 140 MeV beam energy is 14% changing from 1.53 to 1.75 MeV, while the temperature increases from 2.71 to 3.55 MeV. Therefore, the temperature has a significant effect on the inverse cross-section.

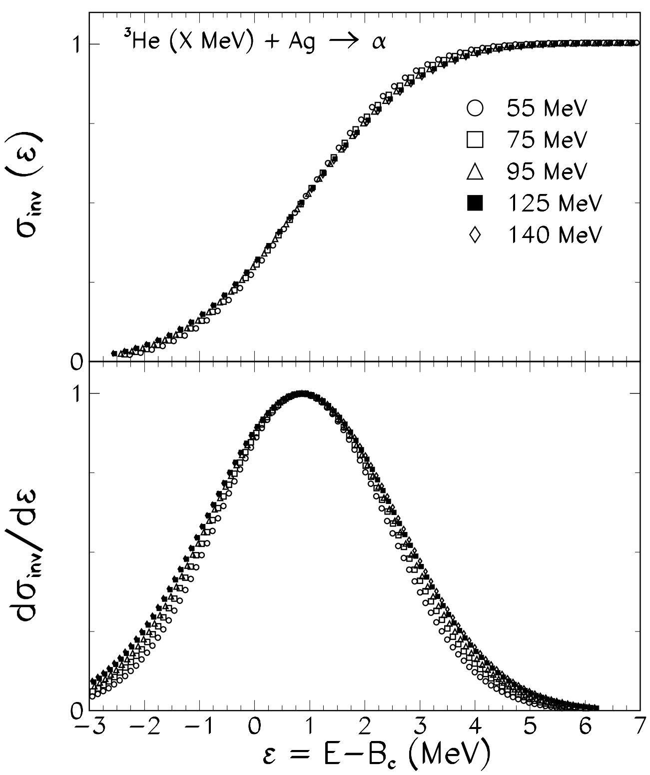

FIG. 1. Top panel: σ_{inv} from the *erfc* function using the parameters obtained from the fit of Eq. (3) to the data. Bottom panel: First derivative of σ_{inv} from Eq. (4).

[1] L.G. Moretto *et al.*, J. Phys. G **23**, 1323 (1997).
[2] L.G. Moretto, Nucl. Phys. **A247**, 211 (1975).
[3] L.G. Moretto and D.R. Bowman, Proceeding of the 25th Meeting on Nuclear Physics, Bormio, Italy, 1987.